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Original Article

AIRPORT PLANNING: APPROACHES TO DETERMINING THE PLANNING HORIZON

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Highlights:

- airport planning horizon methodology development;
- airport planning legal framework analysis;
- airport "ultimate limit" definition;
- fuzzy Delphi Method forecasting technique;
- 2 panels of experts from Slovakia and Croatia.

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Abstract. Airport planning is a challenging task that requires knowledge of many standards and recommended practices, bylaws and procedures. Besides, it is possible that politicians would try to intervene in the planning process, which always exceeds the election period of one government. Therefore, the article provides in-depth theoretical analysis of the problem and summarizes the results of research that focused on comparing the approach to the airport planning issues in the Slovakia and Croatia. The primary goal was to develop a methodology for determining the airport planning horizon, to assess the significance of individual planning phases and to evaluate results. The research was carried out using a combination of several methods. The main challenge was to determine the length of the planning horizon. In 2 panels, 32 experts from Slovakia and Croatia were interviewed and 224 different responses were received and processed by the fuzzy Delphi method. The advantage of this approach relies on combination of well – developed theory and practical solutions in cooperation with experts from the industry. Despite the different legal frameworks and similar standards for airport planning in both countries, the results of the research proved that the values of the optimal planning horizons are comparable. As a result, the methodology can therefore be used in other countries with similar conditions. However, planning procedures and practices depend on the specifics of states or even regions. Eventually, the experience from the research provides relevant and robust material to support teaching. Besides, it is transferable to other fields of transport infrastructure planning. Additionally, the research results were provided to the state planning authorities.

Keywords: airport planning, land use plans, long-term plans, planning methodology, fuzzy Delphi method, expert panels.

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Notations

ADRM – Airport Development Reference Manual;
BPD – Building Permit Documentation;
CCAA – Croatian Civil Aviation Agency;
DI – Democracy Index;
EI – Education Index;
EIA – Environmental Impact Assessment;
EASA – European Union Aviation Safety Agency;
FAA – Federal Aviation Administration;
GNI – Gross National Income;
GPI – Global Peace Index;
HDI – Human Development Index;
IATA – International Air Transport Association;
ICAO – International Civil Aviation Organization;
ICC – Intraclass Correlation Coefficient;
NPIAS – National Plan of Integrated Airport Systems;
OECD – Organisation for Economic Co-operation and Development;
PPD – Planning Permit Documentation;
QFD – Quality Function Deployment.

Introduction and literature review

Civil airport development was associated, on the whole with the emergence of the 1st airlines after the World War I. Originaly, there were no specific rules for airport planning at that time; therefore, procedures and practices for other line infrastructure projects, e.g., railways, were used.

In the early days of civil aviation, airport development and relationship with nearby communities were relatively free of conflicts. The land takes for a major airport, compared to today's requirements, was relatively small. Accordingly, airports were located far from cities where inexpensive land and a limited number of obstructions permitted maximum flexibility in airport operations. Because of the nature of aircraft and the infrequency of flight, the noise was not a problem to the community (Horonjeff *et al.* 2010). Unlike in the present, the airport was a source of pride and a sign of local development from which the neighbouring communities benefited. In line with this, the airport planning horizons usually did not exceed 10 years.

After the World War II, there was a rapid increase in developing civil aviation and air transport. On the one hand, ground communications were damaged while, on the other hand, there were plenty of surplus former military aircraft (Kazda, Caves 2015). The development of some principal European airports was already devised during World War II (e.g., Heathrow), but most of them had to wait until the war ended.

Protests of residents did not limit airports development shortly after World War II in any country affected by the war. This was partly because improvement of the infrastructure was understood as a contribution to local economic growth and job creation. Besides, people had other problems as well. There was no guidance material for airport planning at that time and plans were usually prepared for a 5…10 year period (Kazda 2012).

The jets era advent meant a substantial increase of noise impact from air transport on the neighbouring communities and significant runway extensions because of the jet engine characteristics. Furthermore, the jet airplanes had more demanding geometric characteristics as well. This resulted in greater airport land take and the need to extend airports beyond their original boundaries. Moreover, subsequent conflicts between airports and adjacent urban areas called for the longer planning horizons. To assist states in planning the expansion of existing international airports and construction of the new ones, thus, the Council of ICAO on March 1967 approved a proposal of *Airport Planning Manual – Master Planning* (ICAO 2023).

Accordingly, *Airport Master Plan* is defined as "a guide as to how the airport development should be provided to meet the foreseen demand while maximising and preserving the ultimate capacity of the site" (Kazda, Caves 2015) or "the goal of a master plan is to provide guidelines for future airport development, which will satisfy aviation demand in a financially feasible manner, while at the same time resolving the aviation, environmental and socioeconomic issues existing in the community" (FAA 2005) or "presents the planner's conception of the ultimate development of a specific airport" (ICAO 2023). The prime objective of master planning is to determine the ultimate site capacity and then to protect it from the consequences of ill-considered development of facilities on the airport and the encroachment of incompatible land uses around the airport, which might restrict either its physical expansion or result in traffic limits due to environmental impacts (Caves, Gosling 1999).

The ICAO manual identifies inter alia the planning horizons as follows: short-term (3…5 years in advance) provides the basis for actual development work. In comparison, a medium term forecast (5…20 years, usually in 5 year intervals for convenience) bridges the gap to the long-term and provides interim information on probable subsequent development phases (ICAO 2023). Analogically, similar time horizons are defined in other literature. The IATA ADRM refers to the "projection period" for forecasting and recommends for traffic forecasts short-term (1…5 years projection) and long-term (5…30 years projection) periods (IATA 2022).

As an example of good practice, many airports accepted 20 year planning horizon as "long" and some states still use it. De Neufville & Odoni (2003) refers to "ultimate vision, i.e., a current view of the possible future a long time in the future, for example 20 years".

The provisions on ultimate limits airport development are also included in the ICAO and FAA manuals, but they are often overlooked. Referring to *Airport Planning Manual – Part I – Master Planning* (ICAO 2023), adequate land should be acquired or protected to provide for possible ultimate runway development, including protection of approaches and provision for associated visual and radio navigation (non-visual) aids (ICAO 2023). With respect to *FAA AC 150/5070-6B: Airport Master Plans*, 5-, 10-, and 20 year time frames are typical for short-, medium- and long-term forecasts. Nevertheless, some studies might want to use different time frames (FAA 2005).

Specifically, at some airports, it may be necessary to look beyond the 20 year time frame to protect the airport from incompatible land use development. However, for the sake of planning 20 year period much less detailed outlines than that for the short or even mid-term development. For example, if planning for a future runway, the master plan might only indicate the general location and potential length of the runway (FAA 2005). However, currently, could one consider 20 years as the "ultimate limit"? Might that be horizon appropriate for all the states or regions?

Airport planning practices differ significantly in individual countries and reflect historical experience, airport financing methods, legal framework, political system, the efficiency of state administration, the standard of living, population density and many other factors, which influence the airport planning process and the length of the planning horizon to a certain extent. Nevertheless, the importance of each of the factors differs significantly and they are interdependent. Furthermore, the entire process is very dynamic, where the significance of individual parameters can change, in some cases even by leaps. It is therefore difficult to define their influence exactly. Thus, their impact can vary significantly even within a certain country or region.

With respect to the above-mentioned parameters, it is also necessary to take into account a broader framework concerning such indicators as GNI, life expectancy and EI, which can be expressed by the HDI (UNDP 2022). Besides, important indicator poses the DI, which is a composed index of 60 indicators grouped in 5 categories (EIU 2021).

Furthermore, Governance Indicators being formed by indicators of political stability and absence of violence/terrorism, government effectiveness, regulatory quality, the rule of law and control of corruption impact the planning process significantly (WB 2023). Additionally, the level of societal safety and security, the extent of ongoing domestic and international conflicts and the degree of militarization are also essential for large infrastructure projects planning, such as airports. Those factors could be expressed by the GPI (IEP 2021). The scholars suggest, it is difficult to add capacity to existing airports due to a combination of factors, including a shortage of land, environmental impacts from aircraft and ground traffic. On the contrary, questioning the need for further air travel, inappropriate planning processes, uneven power relationships attempt to manipulate the process emphasizing funding problems and investment risks in the face of uncertainty about future traffic (Caves, Gosling 1999).

For example, US airport operators prepare their plans in line with the national funding agency requirements as they can only get funds from the federal government for projects being in the NPIAS (FAA 2023). Furthermore, projects only get into the NPIAS if they were included in an approved master plan (De Neufville, Odoni 2003). Logically, the long-term visions occur hardly tenable for funding and US airports naturally tend to plan for shorter time horizons.

In the UK the planning process is influenced by a large scale public inquiry. Citizens, as well as various pressure groups, can express their opinions and efficiently block or at least delay the airport development. This is becoming practice in most EU countries, as well.

Preparing *Airport Master Plans* for the so-called "long-term" or 20…30 years' time horizons is a long-established practice. Although, evidence suggests this could be appropriate in some states, in countries where the planning process requires public hearing procedures, it can seriously delay the airport development. In the case of Munich airport, the preparation of the planning process and obtaining a building permit took 23 years and subsequent construction and commissioning of the airport took 7 years (Kazda 2012). A good example of an airport with the 'ultimate vision' development concept is the Charles de Gaulle airport (Paris, France). The airport bought large plots of land for airport development at the right time (Fewings 2001)[1].

All these factors affected to a great extend the evolution of the airport planning processes both in terms of time horizon and planning procedures. A number of aspects related to airport planning in general have already been researched, especially those covering problems of airside capacity (Horonjeff *et al.* 2010), airport strategic planning (Caves, Gosling 1999) or environmental and social issues (Hakfoort *et al.* 2001).

Alternatives to airport strategic planning and airport master planning were the subject of exploration in research by Kwakkel *et al.* (2010). Authors scrutinized 3 alternative approaches to airport planning, found them complementary and proposed combining them into a new, adaptive approach to airport strategic planning. Strategic design parameters of airports in Thailand set out Pandey (2020) who focused in his study on airport airside facilities, aeronautical tariff and other criteria and demonstrated the importance of fuzzy based QFD method for customer-oriented airport strategic planning (Pandey 2020). The case study of the Barajas airport (Madrid, Spain) terminal area master plan carried out an ex-post evaluation of the demand forecasts of the airport's last capacity expansion in 2006 (Sismanidou, Tarradellas 2017) and the article of Tisdall *et al.* (2020) aimed at the problem of "affirmative planning action by stakeholders seeking to replicate international successes". Nevertheless, any of these articles did not investigate optimum planning horizon.

Research of airport planning from the point of view of technical specifications and the airport system capacity in case of airport reconstruction and expansion are investigated by Ke & Bin (2020). Similarly, other articles focus on the development of a framework for the sustainability performance based evaluation of airport project design and technological strategies to enhance the environmental capacity long-term planning during its life cycle (Ferrulli 2016). However, none of those deal with the problems of airport planning horizon.

Another way of using expert view in airport planning is determining the long-term development of an airport's infrastructure, estimate future use of the airport by using peer group learning, which is discussed by Suh & Ryerson (2017). The OECD research is focusing on forecasting methods improvements for airport infrastructure planning including quantitative methods analysis of key drivers for airport demand; expert guidance for data interpretation and risk analysis (ITF 2016).

In order to reduce the likelihood of stakeholder opposition during the master planning process, Rawson & Hooper (2012) are convinced that the airports should engage with stakeholders during this process to achieve a balance of local concerns with national interests and to

[1] Paris Charles de Gaulle airport extends over 3238 ha of land. This vast area was acquired by a limited number of potential relocations and expropriations. The planning of airport and its construction began in 1966 (Airport Technology 2020).

enhance the quality and sustainability of planning documents through increased transparency.

Freestone & Baker (2011) introduced a review of the sustainable airport region, which ultimately requires a rapprochement between *Airport Master Plans* and broader urban planning strategies. Additionally, they also canvass problems in major airport regions in Australia have been exacerbated by the building of highly conspicuous non-aeronautical developments approved with no juddging input by local decision-makers. Apart from that, there occurred the growing pressures on off-airport locations for aviation-related development and, lastly, it gives an overview of the evolving structure of planning controls for Australia's privatized federal airports (Freestone, Baker 2010).

Saldıraner analysed earlier master plans of Turkish airports, which were not brought into effect, indicating that some of the existing applications, such as the coordination, planning, and implementation procedures regarding the airport operators/state-regional planning authorities, need to be changed to clear the way for the development of airports. Otherwise, the latest master plans also will not be fully applicable and existing problems will continue to hinder airport development (Saldıraner 2013). Previously, writers' research focused on the legal framework of airport planning and development in relation to the civil aviation regulations and the lack of links between the *Civil Aviation Act* and the *Building Act* as well as their effect on the sequence of procedures, negotiations, and/or document approval (Kazda 2017). We also researched issues, which may arise during the preparation of line infrastructure projects in the public interest such as airports, railways or highways. We focused mainly on the issue of expropriation of land in the public interest and related problems in Slovakia and Croatia but also in other states. A small number of case studies complemented the theoretical part of the research (Kazda *et al.* 2020).

As there are no binding deadlines for airport planning and development in the respective standards or recommended practices or guidance materials in this research, our primary concern was the determination of an optimal airport planning horizon. Whilst a range of issues connected to airport planning strategies have been covered by existing research, the aspect of time (the optimal airport planning horizon) has not been sufficiently and comprehensively covered yet. For example, the "ultimate vision" or a long-term planning is mentioned by De Neufville & Odoni (2003), however, the concept is based on a good practice and does not rely on research. At the same time, adequate identification of the optimal airport planning horizon is pivotal for both the airport management and the planning authorities. This gap, indeed, reflects the fact that in Europe there are no binding deadlines for airport planning and development.

In this research, the focus is on the determination of an optimal airport planning horizon. Hence, the article will provide important insights firstly, into the development of a methodology for determining the optimal planning horizon of airports in the 2 selected countries. Secondly, to establish the optimal planning horizon of airports and assessment of the significance of individual phases of planning processes and preparation of planning documentation for each of 2 countries. Finally, our exploration will compare and evaluate the results.

1. Methodology

The research was conducted in 2 phases. In the 1st one, the legal frame of airport planning, planning processes and assessment of the importance of each step with respect to the airport planning horizon were analysed. In the 2nd phase, the methodology for determining the optimal planning horizon of airports was developed, the research was carried out and the values of the planning horizon for each of 2 countries were set and the fuzzy Delphi method was used. It was performed in close cooperation with experts from the air transport industry and scholars made the results available to the ministries and transport authorities. Before each of research phases a detailed literature review was conducted.

For the 1st phase of research, scholars adopted multiple research methods. In line with this, a combination of inductive and deductive reasoning was used. The inductive researcher is defined by Creswell & Clark (2017) as "one who uses participants views to construct broader themes and generate a theory". Inductive reasoning is based on learning from experience or collected data. Patterns are observed and recorded in order to reach conclusions (Abudiyah 2020). Moreover, the inductive research approach is usually adopted for qualitative research (Soiferman 2010). As a rule, inductive reasoning enables the researcher to work with a wide range of probabilities, and in variety of ways, it can fuel further exploration or research, allowing the researcher to err and start again. Undoubtedly, scholars must carry out more observations when determining whether their hypotheses are true (Abudiyah 2020). Hence, an inductive approach was used to meet the research objective "to perform an analysis of the outside factors that affect the airport planning horizon".

In the 1st phase, the focus was on data collection and data analysis on airport planning. For this phase of research, a historical method was used. Historical research might require gathering data from situations that have already occurred and conducting analysis on this data just as we would do in a traditional experiment (Kazda 1985). For this part of the research, an extensive set of standards and recommended practices, guidance material published by ICAO as well as other international organizations were analysed. The 1st part of the research can also be termed as explanatory research in which an inductive approach was used. In this case, scholars attempted to determine general rules and recommendations based on known facts and relationships. On the contrary, the problem with the inductive method is often the verification of the results. This was done by comparing findings and solutions from different situations at different airports and states and in the 2nd part of research, specifically, by the fuzzy Delphi method from the Slovak and Croatian expert panels.

It is evident that the planning horizon will differ for various countries, or even regions, depending on factors that could be divided into 3 groups. In the 1st group, one can include issues associated with stability and security of a country. The 2nd group involves factors of state administration and its ability to quickly and transparently manage the submissions of citizens and companies associated with both the planning and building permit project documentation. The 3rd group comprises indicators describing civil society and the level of democracy. Large infrastructure projects such as airports are subject to public hearing procedures in most democratic countries, which could possibly be quite lengthy (Barofsky 2012).

All the factors interact with each other. However, there are also other constraints that may affect the length of the planning horizon. Thus, it might be the availability of obstacle free land, whish can be related to the population density (Kazda *et al.* 2020). As fare as a package of economic issues is concerned, one must take land prices or the method of financing of a project in relation to the type of airport ownership into consideration. Though, these issues are more linked to a specific project.

The logic behind is that all the factors are closely coupled, developing dynamically over time. In some cases, conditions and inputs can change even abruptly. There is also a problem in determining the significance and impact of each factor on the length of the airport planning horizon.

On the other hand, it is possible to estimate the ideal length of the planning horizon by expert estimation. Therefore, it is the type of problem that can be investigated using the Delphi method, which also allows evaluating the importance of salient factors for the length of the airport planning horizon (Rowe *et al.* 1991).

In the research of the airport planning horizon, researchers focused on 2 countries, Slovakia and Croatia. Slovakia and Croatia are similar in terms of size, population, number of airports and they also share the common history of the Austro-Hungarian period. Both states have similar parameters of a standard of living, state governance and democracy (Kazda 2017).

The 2nd phase of research was carried out in 2 stages:
- selection and analysis of factors in relation to the length of the airport planning horizon;
- assessment of the length of the airport planning horizon and determination of the significance of selected factors on the length of the planning horizon by panels of experts using the fuzzy Delphi method.

The Delphi method is a proven and well known; qualitative forecasting technique that has been successfully used in various areas. It has been extensively used in planning, policy analysis and long-range forecasting in both the public and private sectors (Gupta, Clarke 1996). The Delphi method is frequently proposed for the long-term forecasting (Duru *et al.* 2012; Kazda, Caves 2015). The key features of the Delphi method are anonymity, repeated iterations of knowledge elicitation, resolution of differences, advocation of refined opinion and group feedback, all of which are key elements in effective group decision-making (Rowe *et al.* 1991).

The Delphi method is based on the fact that decisions from a structured group of individuals are more accurate than those from unstructured groups (Rowe, Wright 2001). However, the Delphi consensus offers a unique improvement to expert groups via its iterative and anonymous process, which provides revisions of single forecasts according to overall intentions and prevents from individual domination of the group (Duru *et al.* 2012). The term "consensus" is, on the whole, one of the critical concepts of the Delphi like procedures. A consensus defines the degree of agreement on the intended decision task. In most cases, uncertainty is considered to be the opposite of consensus (Zarnowitz, Lambros 1987). It is also one of the multi-criteria decision-making methods (Petrović *et al.* 2019). What's more, Delphi Method is particularly appropriate when there is no historical data "ethical or social dominant economic/technical ones action research" (Rowe *et al.* 1991). In general, Delphi's goal is not to elicit a single answer or to arrive at a consensus, but simply to obtain as many high quality responses and opinions as possible on a given issue from a panel of experts. The rationale for such an approach is enhancement of the decision-making process (Gutierrez 1989) thus capturing a wide range of interrelated variables and multidimensional features common to most complex problems, both of which are necessary elements for scientific analysis in more detail (Ray, Sahu 1990). In most cases, the variable that the group is attempting to predict may take a wide range of values, and it is a crucial task to predict data from a volatile background (Zarnowitz, Lambros 1987). Delphi method has also been implemented for forecasting purposes, such as forecasting economic and political issues (Parenté *et al.* 1984).

As the traditional Delphi method has always suffered from the low convergence of expert opinions, high execution cost and the possibility that opinion organizers may filter out particular expert opinions (Murray *et al.* 1985), the proposed concept of integrating the traditional Delphi Method and the fuzzy theory improves the vagueness and ambiguity of Delphi method (Kuo, Chen 2008). Zadeh (1965) put forward the fuzzy theory, for the sake of reducing system uncertainty in several applications. Fuzzy set theory is an alternative for increasing predictive performance. It ensures consensus incentives and compiles expert expectations (Duru *et al.* 2012). The implementation of the fuzzy Delphi method has been explored by many investigators, for example (Kuo, Chen 2008), or in the technology forecasting study responses on a scale of expert judgments evaluated by Ishikawa *et al.* (1993). While in the traditional Delphi method, experts are required and forced to modify their opinions to meet the mean value of all the expert opinions; if their opinions are not modified, they may be excluded. Thus, it is possible that useful information may be lost. The fuzzy Delphi method respects the original opinions of all the experts (Kuo, Chen 2008). The fuzzy numbers provide a way to process groups of variables rather than the crisp estimates of the conventional Delphi method (Duru *et al.* 2012). It should be noted that the fuzzy Delphi method allows consensus in only one round. The classic Delphi method requires, in contrast, a substantial amout of time for collecting expert opinions as well as considerable experts' time, which may discourage them from participating in research. The cost is high and the fuzziness in the process cannot be excluded.

2. Research

2.1. Fuzzy theory

In the classic, crisp set theory, the element is exactly determined; either element is inside or outside the set. However, in fuzzy theory logic, a set can be defined with unclear boundaries. Let X be a universal set U (Pachauri *et al.* 2013). Then, the fuzzy subset A of X is determined by membership function $\mu_A(x)$ and can be explained by the following mapping:

$$\mu_A(x): X \to [0,1].$$

A fuzzy number A is a special type of fuzzy set that is defined on the set of real numbers R and possesses 3 properties (Cheng, Lin 2002):

- a is a normal fuzzy set;
- the α-cut A^α is a closed interval for every $\alpha \in (0,1]$;
- the support of A is bounded.

For a fuzzy set A in X and real number $\alpha \in [0,1]$, α-cut is denoted by the crisp set:

$$A^\alpha = \{x \in X | \mu_A(x) \geq \alpha\}.$$

Fuzzy Delphi method is divided in 4 steps.

Step 1: fuzzification of the input data. Fuzzification is a process of transformation of the input crisp values $x \in U$ into a fuzzy set $A \in U$ via the membership function. The step in the fuzzification process is to establish the magnitude of the crisp input value x that corresponds to the appropriate fuzzy set A (Musani, Jemain 2013). Later on, input and output values in the fuzzification process can be displayed on a Likert or linguistic scale. In general, 4 types of fuzzifiers can be used in the fuzzification process: singleton, Gaussian, trapezoidal and triangular (most common).

Triangular fuzzifiers transform the crisp values into a fuzzy set A with membership function $\mu_A(x)$ (Figure), which can be expressed as:

$$\mu_A(x) = \begin{cases} 0, & x < a_1; \\ x - \dfrac{a_1}{a_2} - a_1, & a_1 \leq x \leq a_2; \\ a_3 - \dfrac{x}{a_3} - a_2, & a_2 \leq x \leq a_3; \\ 0, & x > a_3. \end{cases} \quad (1)$$

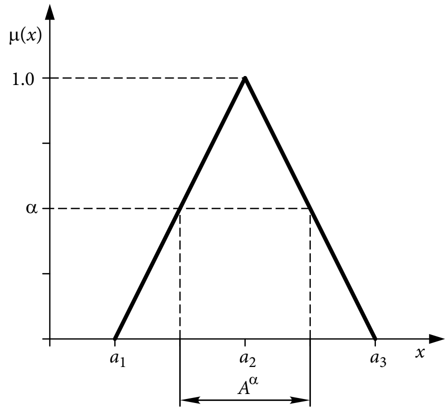

Figure. Triangular fuzzifiers (Cheng, Lin 2002)

The fuzzification is performed based on the analysis of input data and conditions and there is no fixed procedure for transforming the crisp value into a fuzzy set. In the research, the interval boundaries were based on results analysis conducted in similar studies (Dawood *et al.* 2021; Tsai *et al.* 2020; Mohamad *et al.* 2015; Ahmad *et al.* 2014). Therefore, the following fuzzification is applied (Table 1).

Table 1. Likert scale and equivalent fuzzy scale (Dawood *et al.* 2021)

Likert scale	Linguistic scale	Fuzzy scale		
5	very important	0.6	0.8	1.0
4	important	0.4	0.6	0.8
3	average important	0.2	0.4	0.6
2	slightly important	0.0	0.2	0.4
1	unimportant	0.0	0.0	0.2

Step 2: calculate A_{avg} and d value. Based on the transformed triangular fuzzy number defined in step 1, average fuzzy number A_{avg} for each question will be calculated in this step according to the following equation:

$$A_{avg} = (a_{av1}, a_{av2}, a_{av3}) = \frac{1}{n} \cdot \left(\sum_{i=1}^{n} a_{1i}, \sum_{i=1}^{n} a_{2i}, \sum_{i=1}^{n} a_{3i} \right). \quad (2)$$

For calculation of the distance between the 2 triangular fuzzy number $(\tilde{m}, \tilde{n})$, where $\tilde{m} = (m_1, m_2, m_3)$ and $\tilde{n} = (n_1, n_2, n_3)$, a vertex method is defined as follows (Chen 2000):

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3} \cdot b}, \quad (3)$$

where:

$$b = (m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2.$$

Furthermore, each expert and question are necessary to calculate divergence between the average fuzzy evaluation data and the expert's evaluation data (responses obtained from the questionnaire) based on Equation (3).

Step 3: validation of the expert's results. In the following, validation of overall experts' results and particular expert results (the results of each question) was performed.

Overall experts' agreement is based on the 2 criteria: overall experts' consensus and *d* construct. The overall expert consensus was obtained as an average value of expert consensus on each question and must be equal to or greater than 75%. The *d* construct defines itself as the sum of the average threshold value for each question divided by the total number of experts multiplied by the total questions. If the value of the *d* construct is less than the threshold value of 0.2 then, all the experts have achieved a consensus.

Particular expert consensus represents an expert agreement on each question defined in the survey. More precisely, it must have met 3 criteria: (1) average value of expert consensus on the question, (2) *d* value, (3) α-cut. Considering that experts' consensus on the individual question must be ≥75%, the average distance between each fuzzy number and the average fuzzy number must be below $d \leq 0.2$ (Dawood *et al.* 2021), and the fuzzy score A_i must be equal to or greater than the median value of 0.5 (α-cut analysis).

Step 4: defuzzification and ranking process. In the defuzzification process, the fuzzy numbers are transformed into crisp values (fuzzy score). For each $A_i = \left(a_{1i}, a_{2i}, a_{3i}\right)$ can be defuzzified according to the following equation:

$$a_i = \frac{1}{3} \cdot \left(a_{1i} + a_{2i} + a_{3i}\right). \quad (4)$$

There are several different methods for ranking the fuzzy numbers: α-cut method, fuzzy mean method, uniform probability distribution, proportional probability distribution, and others (Chang *et al.* 2011). In the article, ranking order is based on Equation (4).

To sum up, the main advantage of the fuzzy Delphi method for collecting the group decisions underscores the fact that consensus of group decisions involves consideration and integration of every expert's opinion. In addition to fuzzy parts in human thinking, there is a chance of uncertain and subjective messages being possibly induced. Moreover, it reduces the time of investigation and the consumption of costs and time (Kuo, Chen 2008).

2.2. Questionaire and expert panel

The proper selection of experts for panels and the creation of the questionnaire were significant parts of the research. The number of panel members from both countries was 16. All nominated experts had to have experience in airport planning and design. We contacted experts from the transport authority-division of civil aviation, civil aviation authority, special building authority, ministry of transport, consultation/research companies, airports, building companies, academia and chartered civil engineers to attain appropriate diversity of the panel from a professional point of view. Later, when working with experts on the questionaire design, this approach was proved to be appropriate as their views on particular parameters differed, they considered them to be of varying importance. Nevertheless, the basic requirement for accepting experts in the panel was thorough knowledge of airport planning procedures and adequate experience in the field. We strived to structure expert panels from individual organizations from Slovakia and Croatia, as similary as possible. Concerning the similar structure of the panels and the number of panel members, the results from Slovakia and Croatia panels could be compared. Participation of panel experts was on a voluntary basis and none of them terminated their activities during the research. This reflected a high standard of cooperation between academia and the aviation industry in both countries.

In the case of Slovakia, the majority – 6 experts, were from airports with long-term experience in airport operations in senior management positions, 5 from the Transport Authority and the Ministry of Transport, 2 from consultation companies, 2 from academia, and one from a civil engineering – construction company with experience in airport constructions. All of them had more than 17 years of work experience in management positions, on average.

In Croatia expert panel represented the majority (9 experts) the airport professionals, 3 experts were from the CCAA, which also consulted the Ministry of Transport, 2 experts from academia and 2 experts from private consulting companies. They had over 15 years of work experience in management positions, on average.

The questionnaire emerged based on of international legislative framework research (Kazda 2017) of airport planning and the legal specifics of Slovakia and Croatia, land use and compatibility planning requirements (Brown, Raymond 2014), and process for procurement and workout of airport documentation, EIA, public hearing procedure and approval. Although the land acquisition does not influence directly an airport planning, in many countries the planning permit requires the land ownership or a long-term lease agreement at least (Kazda *et al.* 2020). Hence the land acquisition impacting the airport planning process is included in the research, as well.

The initial design of the questionnaire took the airport construction into consideration as well. Later on, however, after having consulted with experts, neither construction, nor final building approval process, and none of commissioning and obtaining the permit to operate would constitute planning process. For this reason, the issue of airport construction financing was not examined either.

In the 1st questionnaire proposal, a total of 13 questions were suggested with an evaluation of a 10 point Likert scale, where experts inquired the importance of individual phases of the airport planning. Experts from Croatia and Slovakia revised this questionnaire. After considering the comments of the experts along with engaging fuzzy Delphi methodology for planning horizon assessment, some questions were aggregated, as well as ranking used to determine the importance/significance of a particular phase of airport planning. In the final version of the questionnair, 7 questions were used in total, plus questions about the respondent's profile.

The 1st question discussed experts' opinions about the optimal airport planning horizon (in years) which was defined as: "a time period during which it is possible to ensure smooth and conflict-free development of airport infrastructure with regard to the requirements of preparation *Airport Master Plan* and obtaining standpoints to it; procurement and preparation of PPD and BPD; EIA; public hearing procedures; obtaining a planning permit and building permit and land acquisition". A typical example of planning horizon for a runway reconstruction, runway extension, or building of a new runway was considered. Respondents could choose lengths of the planning horizon of less than 15 years, further increasing the length in the interval of 5 years up to the possibility of 80 years and more.

In the following 6 questions, the experts were invited to express their opinions on the significance/severity of the impact of the individual phases of preparation, approval, and implementation of the project. Questions were marked A to F and related to issues on the length of the airport planning horizon:

- A – preparation and obtaining standpoints to *Airport Master Plan*;
- B – procurement of PPD, BPD and EIA documentation;
- C – preparation of PPD, EIA and BPD;
- D – public hearing procedure related to the PPD, BPD and EIA;
- E – land acquisition;
- F – obtaining planning permit and building permit.

A 5-points Likert scale was used to evaluate individual factors, where one meant extremely unimportant and 5 extremely important influences on the planning horizon (Table 1).

The questionnaire concluded with questions relating to the expert profile were not processed and were kept strictly confidential.

2.3. Analysis

As mentioned above, the questionnaire involved 3 parts. The 1st part – experts expressed their opinion on the optimal airport planning horizon in years. The 2nd part – they rated how individual phases affect airport planning horizon. The 3rd part – last part contained the expert's identification data, which were not further processed.

As for the submission of questionnaires, the experts received them via e-mails in the form of a word document. Similarly,the results were collected by e-mails, as well. A 100% return of questionnaires was recorded and further processed, all using the fuzzy Delphi method. The results were evaluated separately for Croatia and Slovakia and were compared to each other. For confirmation of the relevance of the overall results obtained by the fuzzy Delphi method, scholars engaged the intraclass correlation and Kendall's *W* methods as well. Schoolars opted for ICC as a descriptive statistic method because the research is made on experts that are organized into groups and it proves how strongly units in the same group resemble each other. The coefficient of concordance, also known as Kendall's *W*, was used for assessing agreement among experts. The results of all the implemented methods and their interpretation are the same.

In the case of Croatia, the 1st part of the questionnaire results indicated that the Croatian experts reached a consensus. The optimal airport planning horizon was 25.62 years, which is also the average value of all the results collected by experts, whilst the median is 27.5 years with a standard deviation of 7.04 years.

If the experts' results are analysed separately, they show that airport and state authorities experts forecast 27.7 and 25 years as the optimal planning horizon, respectively. The experts from academia and consulting companies consider that the optimal airport planning horizon should be shorter and reach the value of 21.66 and 22.5 years. The experts from academia and consulting companies are deeply involved in the airport planning process; however, they are not familiar with all the planning stages (such as public hearings or land acquisition processes). For these reasons, they forecast a slightly shorter planning horizon on average if compared to the airport or government experts.

In the 2nd part of the survey, the experts expressed their opinion regarding the impact of individual phases on the overall planning horizon. The distribution of answers is depicted in Table 2. The scholars established that each phase of the airport planning process had a significant impact on the overall planning horizon. The evaluation of individual phases by experts, in most cases, was assessed as "very important" – Likert scale 5 or "important" – Likert scale 4.

Table 2. Distribution of answers to individual questions from Croatian experts – the 2nd part of the survey

Likert scale	Question [%]					
	A	B	C	D	E	F
5	31.25	25.00	43.75	12.50	68.75	43.75
4	31.25	68.75	56.25	62.50	18.75	31.25
3	37.50	6.25	0.00	25.00	6.25	18.75
2	0.00	0.00	0.00	0.00	6.25	6.25
1	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. The results from Croatian experts of the 2nd part of the survey obtained by the fuzzy Delphi method

Question	d (≤0.2)	Experts' consensus (≥75%) [%]	Average fuzzy number (α-cut ≥ 0.5)	Result	Rank
A	0.215	31	0.588	rejected	0
B	0.123	94	0.642	accepted	2
C	0.150	100	0.688	accepted	1
D	0.134	63	0.575	rejected	0
E	0.210	88	0.700	rejected	0
F	0.234	31	0.625	rejected	0

The 2nd part of the survey process being conducted by the fuzzy Delphi method on 16 experts from the Republic of Croatia indicated that the experts reached an agreement on 2 questions while no agreement was achieved among the experts on the remaining 4 questions (Table 3). Next, questions B and C met all the 3 criteria, and according to the fuzzy Delphi method, expert consensus achieved greater than or equal to 75%, α-cut (average fuzzy number) greater than 0.5; and *d* less than or equal to 0.2 and were accepted in the final evaluation. Additionally, it can be argued that in the segment α-cut (average fuzzy number) in all the questions, a value greater than 0.5 was achieved while the expert's consensus greater than or equal to 75% was achieved in 3 questions. A threshold value *d* less than 0.2 was also achieved in 3 questions.

The results demonstrated that the Croatian experts considered that the preparation of PPD, EIA and BPD had the most significant impact on the overall planning horizon. Furthermore, as the 2nd most important factor influencing the planning horizon, experts considered the procurement of PPD, EIA and BPD on the length of the airport planning horizon.

According to Croatian law, it is necessary to obtain the standpoint or approval of various state institutions after preparing and submitting each of these documents. In some cases, the documents need to be revised even several times. For this reason, most Croatian experts considered that these steps have the most significant impact on the overall airport planning horizon.

For the sake of more detailed analyses, the results from different groups of experts were processed separately. The results obtained from airport experts indicated that a consensus was reached on all the questions, except the last one, which is related to obtaining the planning and the building permit. The experts achieved a very high consensus ranging from 89 to 100% (except the last question) and an overall consensus of 91%, α-cut ranges from 0.578 to 0.756 while *d* ranges from 0.060 to 0.226. The airport experts considered that the land acquisition process has the most significant impact on the planning horizon, while the public hearing procedures related to the PPD, BPD and EIA have the most negligible impact. The above mentioned statements apply especially to the case of Croatian coastal airports, which are located in urbanized areas and regions with strong tourist activity. In these areas, land acquisition is a longstanding process requiring significant financial investments. In most cases, public hearing procedures do not significantly impact the planning horizon since airports have a strong relationship with the local communities owing to the fact they provide many jobs.

From the state authority's expert results, it can be concluded that a consensus was reached among 4 questions. At the same time, 2 questions (A and F) did not satisfy an α-cut greater than 0.5. The government experts expressed their opinions that the preparation of documents PPD, BPD and EIA had the most significant impact on the overall planning horizon stating that the land acquisition process has the most negligible impact. These results could be expected because the state authorities are involved in all the airport planning and construction phases except for the land acquisition. Due to this fact, they cannot adequately evaluate the impact of this phase on the overall planning horizon.

Experts from the University of Zagreb (Croatia) reached an overall consensus with the provision that on 2 questions on which consensus was not reached (A and D), *d* less than or equal to 0.2, and the agreement of experts greater than or equal to 75%. In other cases, a consensus of 100% was reached between the experts, very low *d* (in some instances is 0), which confirms the ideal overlap of results from different experts. These experts and airport experts consider the land acquisition as the most critical factor influencing the planning horizon. Simultaneously, they thought the most negligible impact was the procurement of certain documents related to the airport's construction.

The fuzzy Delphi method indicates a large dispersion of results among experts from private companies. Among these experts there was a perfect overlap on certain questions, (B question – procurement PPD, BPD and EIA documentation; *d* = 0.000, expert consensus = 100%, α-cut = 0.600). Conversely, they had diametrically opposite conclusions in others (E question – land acquisition; *d* = 0.458, consensus of experts = 0%, α-cut = 0.500). The obtained results correspond to the profile of experts from private consulting companies, as each of them deals with a specific segment of airport planning and for these reasons, there is a large dispersion of survey results.

In the case of Slovakia, the results of answers to the 1st question – the length of the planning horizon is shorter, but not significantly, than in the case of Croatia. The mean – the average length of the planning horizon was 23.75 years, with a median (close to the average value) of 22.5 years and a standard deviation of 9.1 years. The standard deviation for the planning horizon in Slovakia is more extensive than in the Croatia's case. The reason could be the different experience of experts from the largest airport, e.g., Bratislava, being capital, where the hearing process is more demanding on the one hand and smaller airports in the preparation of projects on the other hand. Moreover, some state administration experts opted for shorter planning horizons as they are not familiar with the problems of acquiring land for infrastructure development.

Answers from Slovak experts to the 2nd part of the survey are shown in Table 4. Most of the factors were evaluated as "very important" – Likert scale 5 (46% of all answers) or "important" – Likert scale 4 (30% of all answers).

Various external conditions, as well as different staffing of investment activities at large and small airports, are reflected in the answers to the questions of the most significant/critical factors influencing the length of the planning horizon. As the most critical stages of the process experts considered land acquisition (E question – *d* = 0.200, consensus of experts = 81%, α-cut = 0.713). This fact could reflect the great fragmentation of land ownership in Slovakia, problems in identifying unknown owners and land purchase. A high consensus of experts – 81% was also reached on question A with α-cut = 0.638; however, the value of the *d* = 0.248 did not meet the specified criterion and, therefore, the result had to be rejected (Table 5). A high consensus of experts in this question may indicate problems with preparation and obtaining standpoints for *Airport Master Plans*. It could be due to the lack of a strategic document on air transport and airports at the government level, which has never been prepared in Slovakia.

In addition, in the case of Slovakia, a more detailed analysis of answers of expert sub-groups, depending on where they are employed, was conducted.

In the case of airport experts, the conclusions could not be accepted for any of the answers. As already mentioned, this is partly due to diametrically different external conditions at small airports and the airport of the capital (Bratislava), but also different personnel conditions when dealing with investment project requirements. The only question where a high consensus of airport experts was reached was D, i.e., public hearing procedure related to the PPD, BPD and EIA (*d* = 0.204, consensus = 83%, α-cut = 0.700). These procedures are related to the Slovak legal acts, which are applicable, so the consensus is right. To put it simply, all airports are subject to the public hearing procedure and therefore a high consensus has been reached.

On the contrary, a high degree of agreement in experts' answers from the state administration (Transport Authority and the Ministry of Transport) was recorded, where it was possible to accept answers to all questions except the question D – public hearing procedure. In the case of university experts, a high agreement was reached on all answers.

Table 4. Distribution of answers to individual questions from Slovakian experts – the 2nd part of the survey

Likert scale	Question [%]					
	A	B	C	D	E	F
5	50.00	18.75	50.00	43.75	75.00	37.50
4	31.25	37.50	31.25	31.25	6.25	43.75
3	6.25	31.25	0.00	12.50	18.75	6.25
2	12.50	12.50	12.50	12.50	0.00	12.50
1	0.00	0.00	6.25	0.00	0.00	0.00

Table 5. The results from Slovak experts of the 2nd part of the survey obtained by the fuzzy Delphi method

Question	*d* (≤0.2)	Experts' consensus (≥75%) [%]	Average fuzzy number (α-cut ≥ 0.5)	Result	Rank
A	0.248	81	0.638	rejected	0
B	0.253	63	0.529	rejected	0
C	0.284	31	0.617	rejected	0
D	0.251	31	0.613	rejected	0
E	0.200	81	0.713	accepted	1
F	0.215	44	0.613	rejected	0

In this research, the authors aimed to identify the optimal planning horizon and the key activities in this process. Analysis of the survey showed that experts in both countries consider a similarly long planning horizon, which is consistent with the long-established international practice of airport planning for a long-term period of 20...30 years. This paradigm is consistent with the guidelines of the ICAO, which generally defines 20 years as the long-term period for airport master planning.

As can be seen from the preceding discussion, most experts rely on ICAO guidelines to determine the optimal planning horizon. The reason for this is that most of them do not take a comprehensive approach and are only involved in a specific phase of airport master planning (experts from academia, for example, are not involved in the land acquisition process). This is a subjective approach, and if we want to analyse this issue from an objective point of view (defining an objective length of the planning horizon), we need to identify the key activities of the master planning process. Further analysis of the key activities in the planning process will allow to identify the differences between the procedures and practises in different countries, and to specify particular time horizons for each activity and redefine the 'overall' planning horizon.

An important conclusion of this section is that there are different views on the complexity of the various stages of the airport planning process, depending on the professional experience of the expert and his/her job position. Therefore, the preparation and assessment of airport development projects must be carried out in a broad-spectrum team both professionally and personally and with as much open communication as possible.

Despite the relevance of this research, the study has the following limitations: (1) the number of experts included in the questionnaire, which is relatively small, especially when considered from the perspective of individual organizations, and (2) the number of countries included in the study and their socioeconomic characteristics.

Future studies should include a broader panel of experts with a relatively high number of experts from different countries, potentially leading to greater diversity in expert responses and enabling comprehensive horizon planning for a one world region. The negative implications of this approach can be seen in the need to conduct multiple rounds to reach a consensus among experts from different countries. In some cases, this may lead to uncertainty if the experts do not reach consensus. Another approach to this problem could be to involve experts from international consulting firms engaged in airport development projects in different countries.

Conclusions

The issues of airport planning and development in relation to the air transport market needs to count to the most difficult managerial challenges within the air transport industry. Consequently, incorrect decisions can have far-reaching impact, potentially affecting airport existence.

Analogically, The fact that the airport development project in most cases exceeds the period of one airport management might caused the situation further worsen.

The research revealed that standards for airport planning do not exist in many countries. The scholars chose 2 countries being similar in size, population, number of airports, and besides, having a common history and comparative national legal framework of airport planning. However, globally, there are international recommendations that are not ideal for all the countries. Presumably, it would be advantageous to have a "formula" defining the optimal planning horizon based on explicitly determined indicators. Unfortunately, nothing like this is possible. The optimum planning horizon depends on several variables, which are dynamic and unique for each state or even a region. This was found in the previous research of the authors and was confirmed by recent investigations.

In line with these findings, Slovak and Croatian airport planning legal frameworks are comparable and face similar problems. It could be concluded that the legal framework is of the same salience as the standards, implementation and interpretation of procedures by responsible state authorities, i.e., transport authority/civil aviation authority and the ministry of transport. Of the utmost importance for the airport planning processes pose strategic plans for civil aviation, which could serve as a base for creating the regional strategies and airport development concepts. A well-founded high-level strategic plan could reduce the number of unknowns and variables that might affect particular airport development. The resistance against an airport expansion is typically higher in countries with a higher standard of living. Residents usually appreciate the quality of their lives and object to the airport development, which is generally connected with environmental problems, pollution and generates ground transportation. On the contrary, investors usually claim economic benefits for the region and adjacent metropoles. Ultimately, citizens might benefit from enhanced air transport links and new job creation.

In the 2nd part of the research, scholars combined different research methods, particularly the fuzzy Delphi method and ICC and Kendall's *W* methods, to confirm results and relevance of the overall consensus of the fuzzy Delphi method. The methods explained in detail in the article, are duly justified, provide robust results and can be used by researchers in other countries for optimal airport planning as well as for other infrastructure development. In conjunction with these views, it is obvious the fuzzy Delphi method as a suitable method, allowing thus reduction the number of iterations, i.e., contacts with experts in the panel, which is only advisable. In turn, this increases the willingness of experts, who are often very busy, to participate in similar research. For this reason the method is also a powerful tool suitable for doctoral thesis projects. Eventually, the experience from the research is transferable to different infrastructure planning areas.

The effect of other factors influencing the optimal planning horizon, which could include indicators as a standard of living, level of democracy, political stability and the absence of violence, the rule of law and level of corruption, government efficiency and other culture, economic and social aspects were beyond the scope of this research. Conclusively, the identification of to what extent these factors influence the horizon planning process could be a goal of the future research.

The research analysed the legal framework, standards and recommended practices and guidance material on airport planning. Based on the results of the research, a procedure and a method are proposed for airport planning horizon determination. The research result, based on the 2 countries, indicates that it is necessary to re-consider and revise planning standards and recommended planning horizons.

In the developed world's region (such as the EU), due to the complex legal procedures and land acquisition problems, it is needed to opt for a longer planning horizon compared to the current international guidance materials recommendations.

Last, but not least, it should be emphasized that the principal document for airport planning – the *Airport Planning Manual – Part I – Master Planning* (ICAO 2023) was published in 1967 for the 1st time and the current – 2nd edition appeared in 1987. Therefore, the document does not meet current requirements and future challenges covering in particular the environmental issues but also changes in society. With respect to this, we plead for an update of this ICAO document as very urgent and, similarly, the creation of EASA guidance material covering airport long-term planning. Though the IATA ADRM is not a standard, it involves recommendations on airport land use planning and airport master planning. For this reason, it is possible to recommend its update as well.

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Author contributions

Antonín Kazda conceived the study and wrote the 1st draft of the article.

Antonín Kazda investigated the airport planning practices and standards.

Alena Novák Sedláčková analysed legal documents related to the airport planning framework.

Antonín Kazda, *Alena Novák Sedláčková*, *Matija Bračić* were responsible for data collection.

Matija Bračić was responsible for establishing the model and data analysis.

Antonín Kazda, *Alena Novák Sedláčková*, *Matija Bračić* were responsible for data interpretation.

Antonín Kazda, *Alena Novák Sedláčková*, *Matija Bračić* were responsible for article preparation.

Antonín Kazda, *Alena Novák Sedláčková*, *Matija Bračić* reviewed the results and approved the final version of the manuscript.

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